FIELD OPERATIONAL TEST ON NEXT-GENERATION ROAD SERVICE IN JAPAN

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Abstract

In Japan, efforts are being made to promote “Smartway”: systems enable road users to increase their convenience and safety by adding services. As part of this promotion, the National Institute for Land and Infrastructure Management (NILIM) of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has, in recent years, carried out public-private joint research on next-generation road services using ITS technologies. NILIM also carried out Smartway Demo 2006, a proving ground for reporting and publicizing the research results. NILIM placed the roadside equipment and prepared a new on-board unit to conduct field operational tests on the Metropolitan Expressways. The outcome of the series of tests provided valuable input to “Smartway Demo 2007”, which served as a good opportunity to introduce the public to the achievements of our years-long research and development effort. In FY2008, trials were also carried out on public roads in three major metropolitan areas (Tokyo, Aichi and Osaka etc.) to achieve nationwide deployment. This paper reports the result of the 2007 and 2008 tests.

1. Introduction

In Japan, traffic accidents cause 5,155 fatalities per year (2008), and it has a tendency to decrease from year to year. However, total accidents and the number of injured both remain high, at about 770,000 accidents and about 950,000 injuries. This means that reduction the number of accidents is an urgent challenge, and one way to do so is to introduce ITS (Intelligent Transport Systems). Conventional traffic accident measures were primarily measures taken in advance such as road improvement and traffic safety education, measures during and immediately after accidents including the legal requirement to fasten seat belts, installation of airbags, etc., and measures taken later, typically providing emergency information and improving emergency medical treatment. Measures implemented immediately before accidents have not been given very much consideration until now. To introduce measures to be implemented immediately before accidents, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has undertaken research and development of Advanced Cruise-assist Highway Systems (AHS) which provide vehicle-highway communication by performing real-time communication between vehicles and sensors, beacons, etc. installed at roadside. The MLIT is now promoting Smartway: systems enable road users to increase their convenience and safety by adding services.

This report introduces an outline and the results of field operational tests performed by the NILIM.

2. Outline of next-generation road services

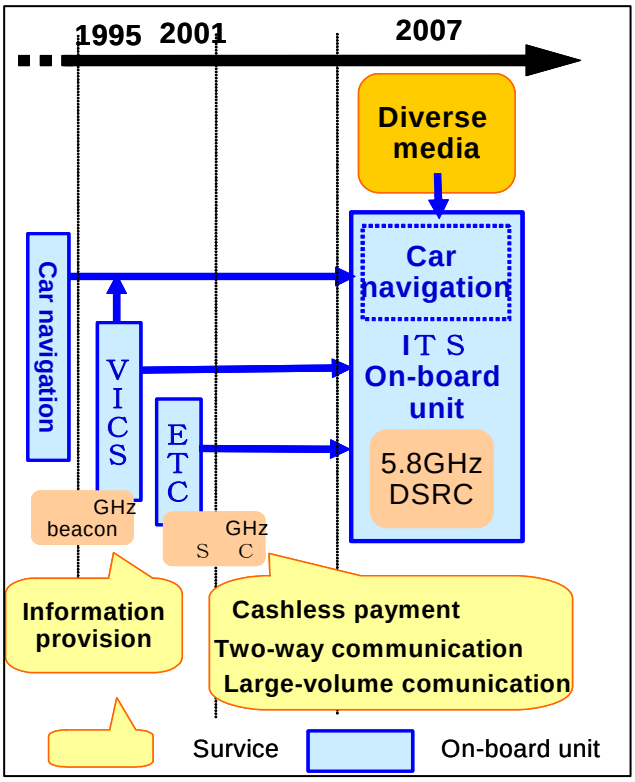

Figure 1. Integration of existing services

Smartway, which is a next-generation road service being developed by the MLIT, is defined as, “A road on which vehicles, drivers, and other road users can use advanced ITS technology to exchange various kinds of information”. Next-generation road services utilize two-way communications based on 5.8GHz band DSRC (Dedicated Short Range Communication) which is the communication technology adopted by ETC (Electronic Toll Collection) in Japan, and vehicle to infrastructure cooperative system with high functioning car navigation equipment as their major constituent element. In addition to the functions of VICS (Vehicle Information and Communication System) which has provided real time road traffic information since it started service in 1995 and ETC systems which started service in 2001, it includes functions which provide information for safer driving, road traffic information, and so on both visually and audibly, plus IP connection functions, EMV credit card payment functions, and others. One special feature is that, as shown by Figure 1, these diverse services can be utilized with one on-board ITS unit.

To realize these services, the NILIM of the MLIT and 23 private companies conducted a public-private joint research for about 1 year from February 2005 until March 2006. In order to present the achievements of this joint research, Smartway Demo 2006 was held in February 2006 at the test course of the NILIM, confirming that the safe driving support system which was studied had reached a technologically practical level. In response to the results of the joint public-private sector research, standards and specifications were finalized for both roadside unit and on-board units in March 2007.

Figure 2 shows the ITS on-board unit which has been developed. The developed ITS on-board units includes two types: one called a voice type on-board unit that provides only audio information by sound and voice, and another called a navigation linked ITS on-board unit which provides both audio and visual information by linking to car navigation systems.

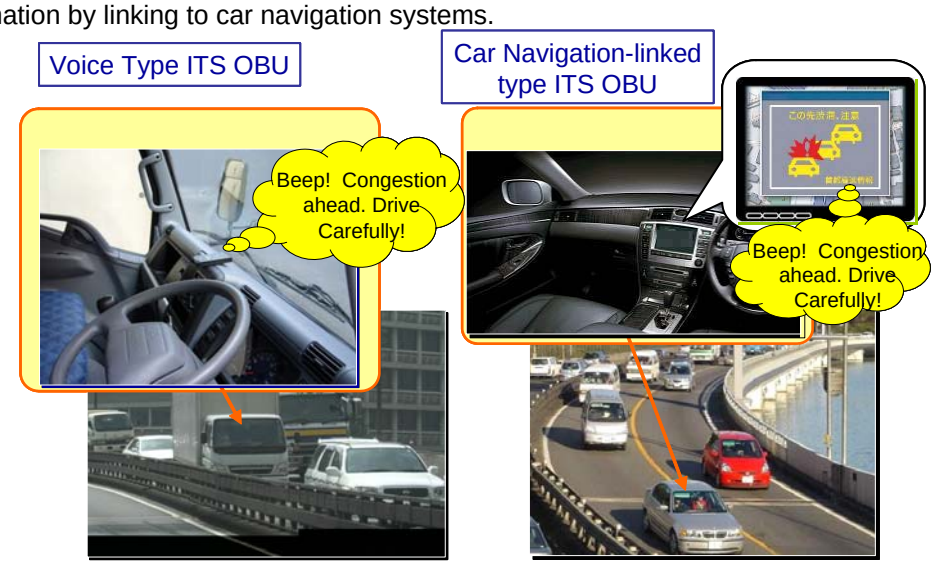

Figure 2. ITS On-board Units

3. Outline of field operational tests and developed services

3.1 Outline of field operational tests in FY2007

The following is an outline of tests performed in FY2007. During that year, equipment was actually equipped and used for field operational tests based on the standards and specifications for road-side unit and on-board units decided up to FY2006. The field operational tests were performed on the Metropolitan Expressway and provided the services: Providing Information on Obstacles Ahead, Merging Assistance and Providing Information on Conditions Ahead (still pictures, highway advisory radio). The field operational tests were performed twice (First field operational test, Second field operational test) and these were combined in the Smartway 2007 Demo. The First field operational test confirmed that the systems functioned accurately and that providing information on-road did not cause drivers to take hazardous behavior such as sudden braking or abrupt steering. This was followed by the Second field operational test, held to improve these systems and to allow automakers, electric maker, road administrators, members of concerned outside organizations and other concerned parties to verify the services. And in order to widely inform the general public about the developed services, Smartway Demo 2007 was performed for the public from October 14 to 17, 2007. Smartway Demo 2007 tested Parking Fee Payment, Providing Information at Road Stations, SA (Service Area), and PA (Parking Area), Digital Map-Linked Driving Support Service and Electronic Sign services, in addition to Providing Information on Obstacles Ahead, Merging Assistance, and Providing Information on Conditions Ahead (still pictures, highway radio). Table 1 presents an outline of the field operational tests held in FY2007. The contents of the services provided during Smartway Demo 2007 are shown in Figure 3, while the locations of the services provided on the Metropolitan Expressway are shown in Figure 4.

Table 1. Outline of the FY2007 Field Operational Tests

Category	Service menu	Test period	Subject	Number of subjects	Data obtained
First field operational test	Providing Information on Obstacles Ahead	April, 2007	Ordinary drivers	56	Vehicle behavior data Questionnaire survey
	Merging Assistance	April and Sept., 2007	Ordinary drivers	50 each	Vehicle behavior data Roadside, on-board camera data Questionnaire survey
	Providing Information on Conditions Ahead (still pictures, highway radio, simple diagram)	May to June, 2007	Concerned outside persons	158	Questionnaire survey
Second field operational test	Providing Information on Obstacles Ahead	May to Nov., 2007	Concerned outside organizations	Automakers etc. (30 companies) etc	Same as First field operational tests
	Merging Assistance	May to Nov., 2007	Concerned outside persons	259	Same as First field operational tests
	Providing Information on Conditions Ahead (still pictures, highway radio, simple diagram)	July, 2007	Concerned outside persons	40	Same as First field operational tests

Smartway 2007 Demo	• Providing Information on Obstacles Ahead • Merging Assistance • Providing Information on Conditions Ahead (still pictures, highway radio) • Parking Fee Payment • Providing Information at Road Stations, SA, and PA • Map-linked Cruise Assistance • Electronic Signs	Oct. 14th to 17th, 2007	Visitors to the demo	Approx. 670	Questionnaire survey

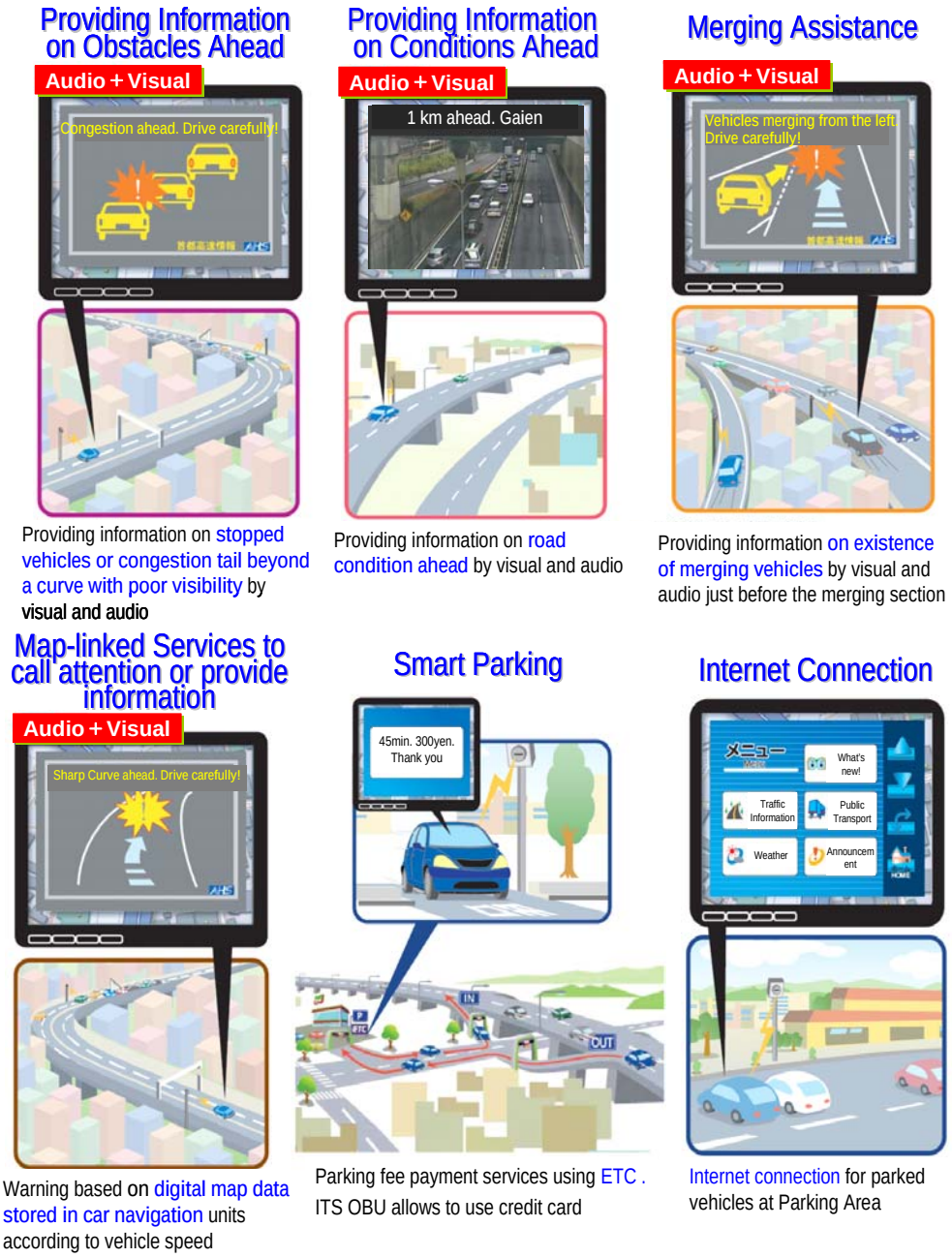

Figure 3. Services Provided at Smartway Demo 2007

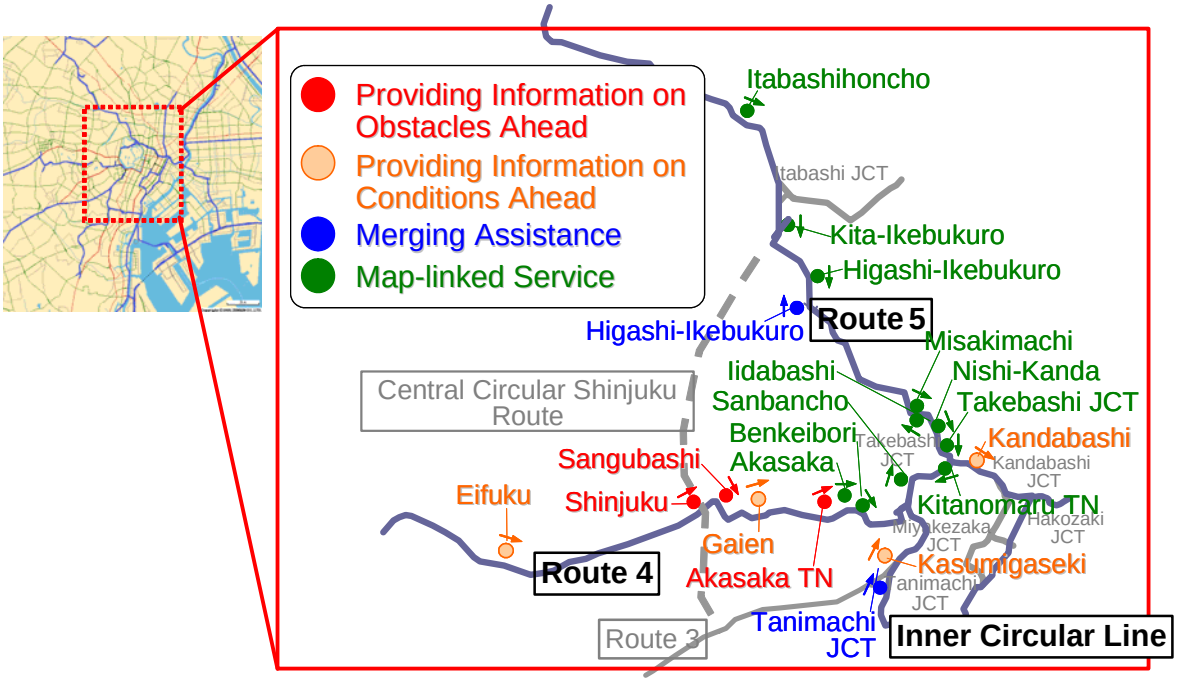

Figure 4. Location of Field Operational Test in Metropolitan Expressway

3.2 Outline of the field operational tests in FY2008

In FY2008, based on the results of research up to FY2007, field operational tests were held, mainly in the three large metropolitan regions in order to introduce Smartway nationwide. Table 2 shows excerpts from the test outline.

Table 2. Outline of Field Operational Tests in FY2008

Test location	Service menu	Test period	Subjects	Number of subjects	Data obtained
Tokyo region (Metropolitan Expressway)	Providing Information on Obstacles Ahead	February to March, 2009	Ordinary drivers	60	• Vehicle behavior data • Roadside, on-board camera data • Questionnaire survey
	Providing Information on Conditions Ahead (still pictures)	February to March, 2009	Ordinary drivers	32	Questionnaire survey
	Providing Information on Road Traffic Conditions	March, 2009	Ordinary drivers	13	Questionnaire survey
Keihanshin region (Hanshin Expressway)	Providing Information on Obstacles Ahead Merging Assistance	March, 2009	Ordinary drivers	10	• Vehicle behavior data • Roadside, on-board camera data • Questionnaire survey
	Preventing Danger Entering Curves	July and Nov., 2008	Ordinary drivers	71	• Vehicle behavior data • Roadside, on-board camera data • Eye-camera • Vital sensor data • Gyro sensor data • Questionnaire survey

	Providing Information on Conditions Ahead (still pictures)	March, 2009	Ordinary drivers	15	Questionnaire survey
Keihanshin region (West Nippon Expressway)	Providing Information on Conditions Ahead (highway radio)	March, 2009	Ordinary drivers	32	Questionnaire survey
Aichi region (Nagoya Expressway)	Providing Information on Obstacles Ahead Preventing Danger Entering Curves	March, 2009	Ordinary drivers	10	• Vehicle behavior data • Roadside, on-board camera data • Questionnaire survey
Niigata region (Kan-etsu Expressway)	Vehicle behavior data collection	–	System confirmation by concerned insiders	–	–

4. Results of field operational tests

Below outlines of the systems and principal test results concerning the field operational tests introduced in Part 3, particularly Providing Information on Obstacles Ahead (Rinkai Fukutoshin Exit, Tokyo Metropolitan Expressway, FY2008), Merging Assistance (Metropolitan Expressway, Tanimachi Junction, FY2007), and Preventing Danger Entering Curves (Hanshin Expressway, Miyake Curve, FY2008), tests of AHS.

4.1 Providing Information on Obstacles Ahead

The service called Providing Information on Obstacles Ahead is a service which reduces rear-end collisions: sensors on the roadside detect stopped and slow-moving vehicles beyond curves or crests which obstruct drivers' view of the road ahead, then supply this information to approaching vehicles through DSRC roadside units. Figure 5 shows an outline of the Providing Information on Obstacles Ahead service system.

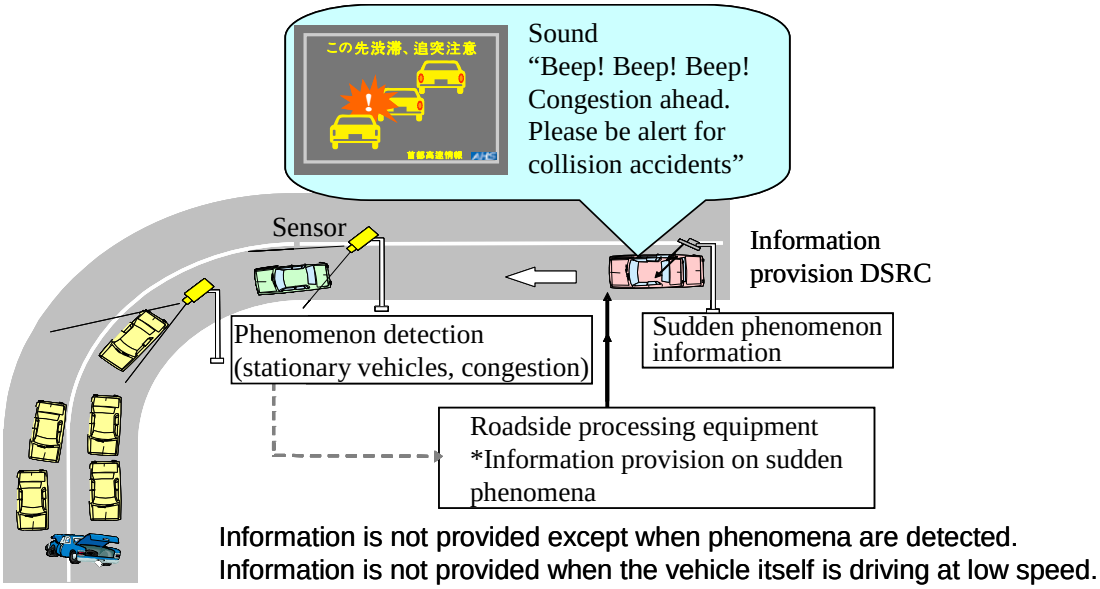

Figure 5. Outline of the Providing Information on Obstacles Ahead Service System

4.1.1 Test results

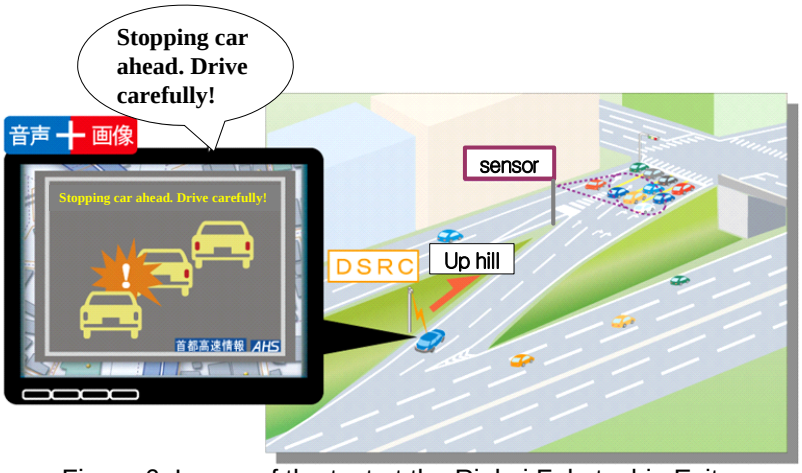

Figure 6. Image of the test at the Rinkai Fukutoshin Exit

By FY2007, tests had been performed on the Sangubashi Curve (inbound) and on the Shinjuku Curve (inbound) sections of the Route No. 4 Shinjuku Line of Metropolitan Expressway. Then in FY2008, tests of the service on crests and continuous curves and tests of a service combining it with Merging Assistance and Providing Information on Conditions Ahead, services described below. This report presents the results of tests performed at locations of crests.

At the Rinkai Fukutoshin Exit on the eastbound Bay Shore Route of the Metropolitan Expressway, there is a level intersection of ordinary roads at the end of the off-ramp. And because the ordinary roads are at ground level and the expressway is below ground level, there is a crest on the off-ramp, so it is difficult for drivers of cars emerging from the off-ramp to see the signals or cars stopped waiting for the signals at the level intersection. The major special feature of this test is that it provided information about obstacles beyond a crest instead of beyond a curve. Figure 6 is an image of the test at the Rinkai Fukutoshin Exit.

Figure 7 and Figure 8 show the results of this test. Figure 7 shows the traveling speed distribution. It confirmed that providing the information reduced speeds, as the traveling speed distribution was slower with the service than it was without the service. The results of the questionnaire survey in Figure 8 show that nearly 90% of all test subjects answered that, “it was good because I knew in advance that a car was stopped or that there was an intersection and prepared mentally”. But 3% answered, “It is unnecessary because drivers travel slowly on the rising grade.”, indicating that the subjects felt the usefulness of the service.

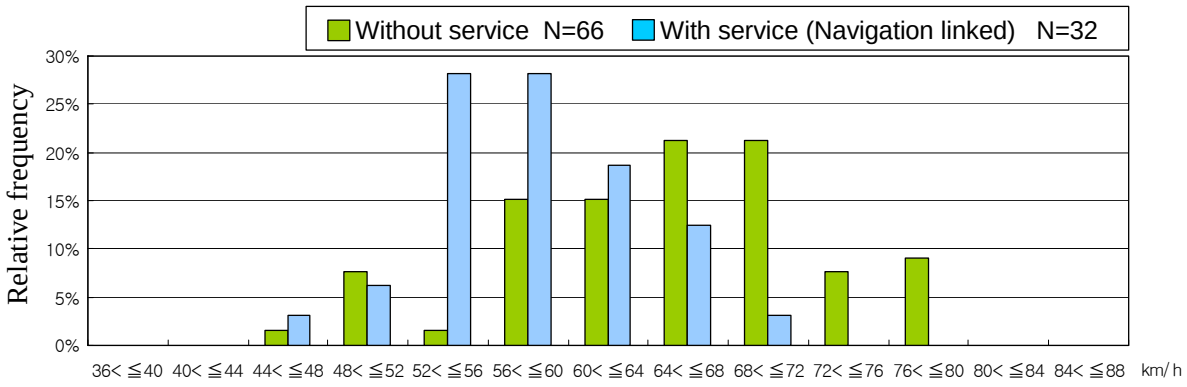

Figure 7. Traveling Speed Distribution at the Rinkai Fukutoshin Exit

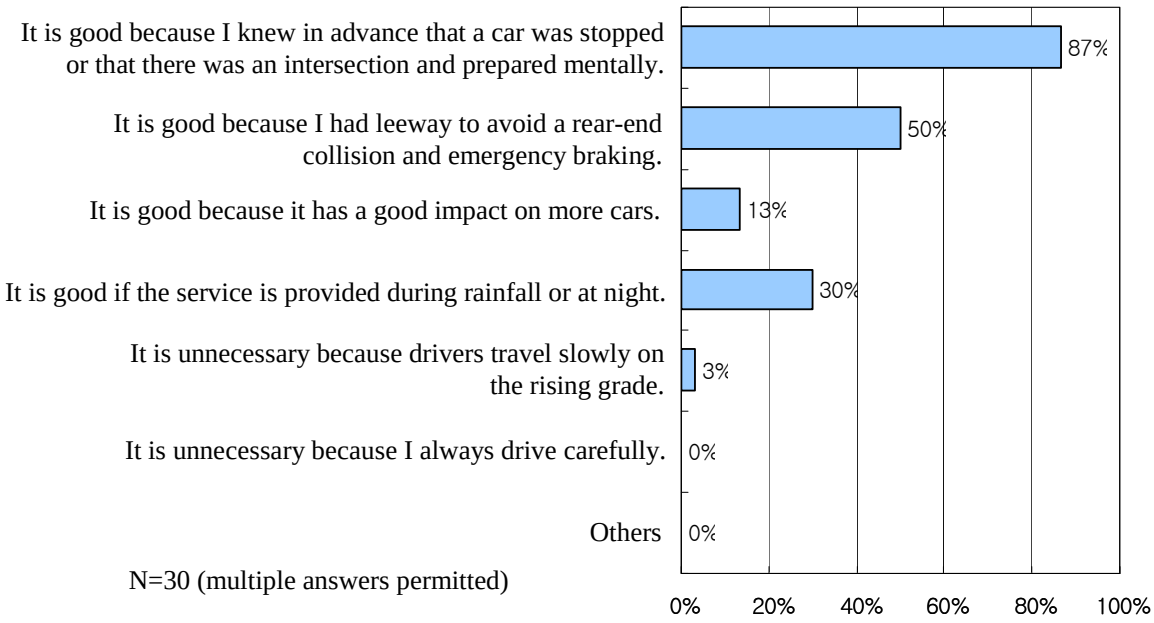

Figure 8. Results of Questionnaire Survey Concerning Providing Information on Obstacles Ahead Test at the Rinkai Fukutoshin Exit

4.1.2 Development of a new obstacle ahead detection system

Image processing sensors have been used as roadside sensors to detect stopped or slow-moving vehicles beyond curves and crests where visibility is poor, but an ETC-ID detection system which is cheaper to install and which can detect stopped or slow-moving cars is introduced.

The ETC-ID equipped detection system utilizes ETC-ID which are anonymous because they are generated by random numbers each time the power to the on-board unit is turned on. As shown in Figure 9, the system collects ETC-ID from DSRC antennas installed at two locations - the entrance and exit of the phenomenon detection zone - and when an ID of an ETC on-board unit equipped vehicle received by the ETC-ID collection DSRC antenna at the entrance cannot be received by the ETC-ID collection use DSRC antenna at the exit within a standard time period, the system judges that the vehicle has been stopped either by congestion or by a stopped vehicle etc. in the phenomenon detection zone, and supplies this information to alert following vehicles. While this system is beneficial in that it permits the installation of the equipment for a lower cost than image processing sensors, it has a shortcoming. Because it uses an algorithm to judge if the car has been stopped by congestion or a stopped car when the ID collected at the entrance is not detected at the exit with a standard time period, there is a time lag between the occurrence of the phenomenon and its detection.

A comparative test of the performance of the ETC-ID method with that of the image processing sensor was performed on the Sangubashi Curve (inbound) on Route No. 4 Shinjuku Line of Metropolitan Expressway in FY2007. As a result of the field operational test and comparison with the image processing sensor system, it was confirmed that the system of detecting forward obstacles using ETC-ID had a performance enough to detect the velocity lowering caused by congestion etc.

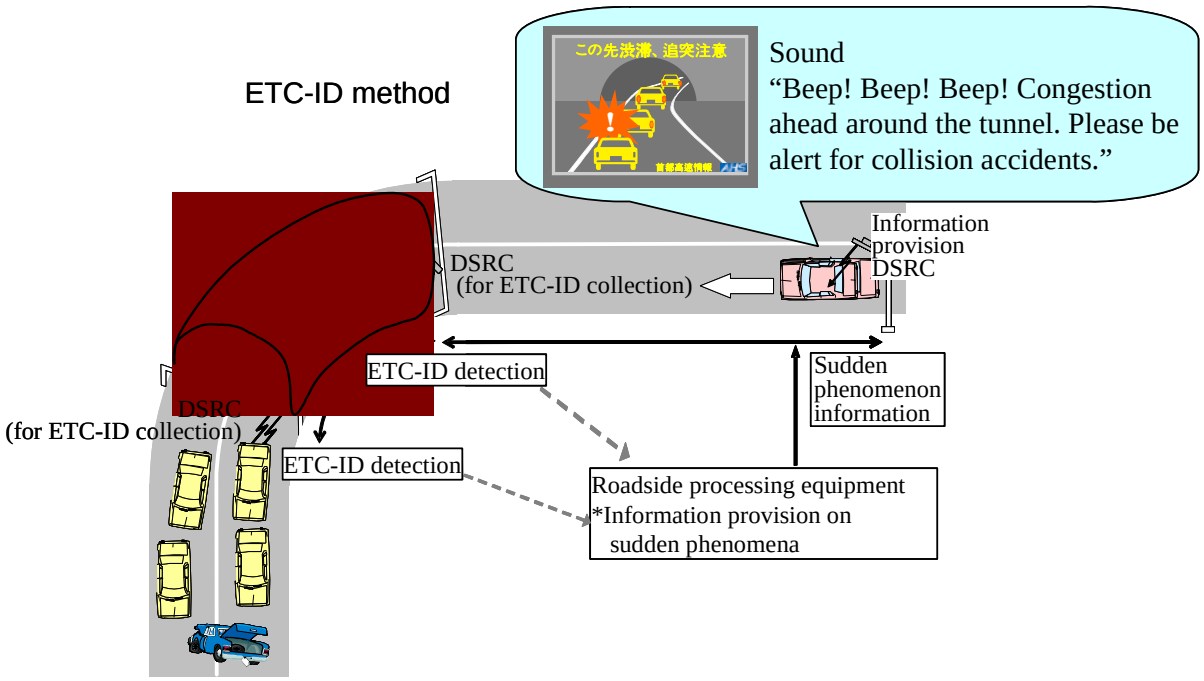

Figure 9. Providing Information on Obstacle Ahead by the ETC-ID

4.2 Merging assistance

The merging assistance service is a service which, as shown in Figure 10, uses sensors installed on the road-side at merging sections of expressways to detect merging vehicles and provides timely information concerning the merging vehicles to vehicles on the main lane.

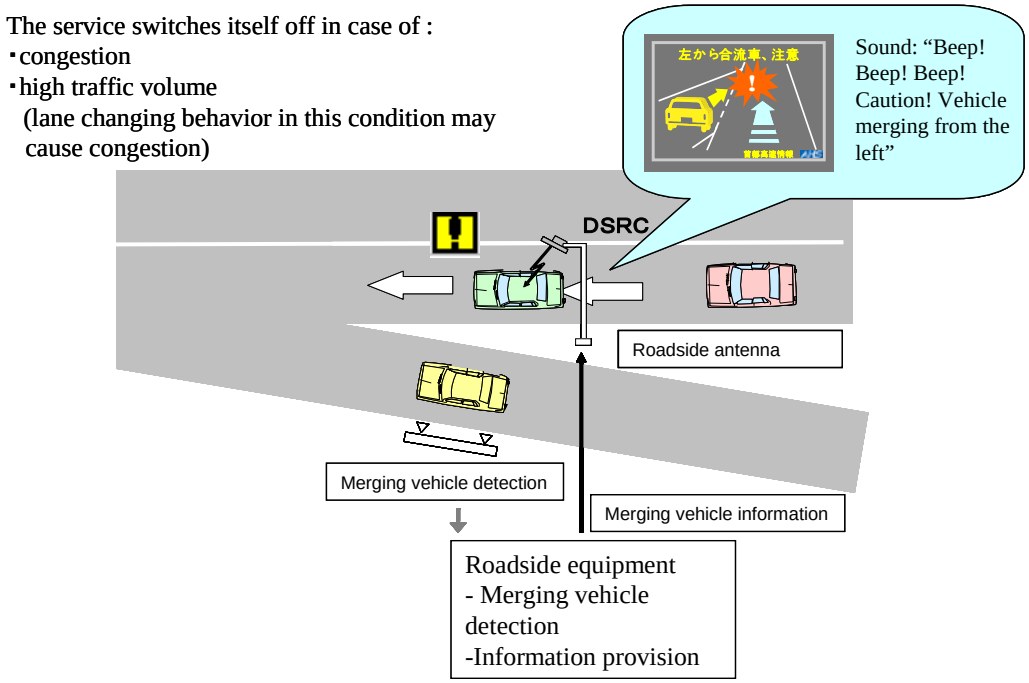

Figure 10. Image of Merging Assistance Service

The tests on the Metropolitan Expressway in FY2007 were performed at Route No. 5 Ikebukuro Line, Higashi-Ikebukuro Ramp (outbound) and Inner Circular Route, Tanimachi Junction (clockwise). The results of the tests confirmed that vehicles on the main lane prepared promptly when provided with information about the approach of merging vehicles, and showed that they did not respond in a hazardous behavior, sudden deceleration or abrupt steering, when provided with this information. The results also showed that it not only prevents accidents but provides drivers with an enhanced feeling of safety.

Below, part of the results of the test at Tanimachi Junction is introduced. Figure 11 aggregates the positions where the test drivers prepare for deceleration by distance from the position of the DSRC roadside unit. The results confirm that without the service, drivers started to prepare for deceleration 60m from the DSRC roadside unit position, but with the service, they were aware of the merging vehicle (or of the merging section) earlier, and began preparing to decelerate. And even in the case of the separately conducted questionnaire survey, some answered, “I was aware of the approaching merging vehicle (or merge) in advance, so I was in a relaxed frame of mind.” indicating that the service permits drivers to drive their vehicles without a feeling of urgency.

◇ **Cumulative distribution of where braking occurred (with/without information) at Tanimachi JCT** <advance proving tests>

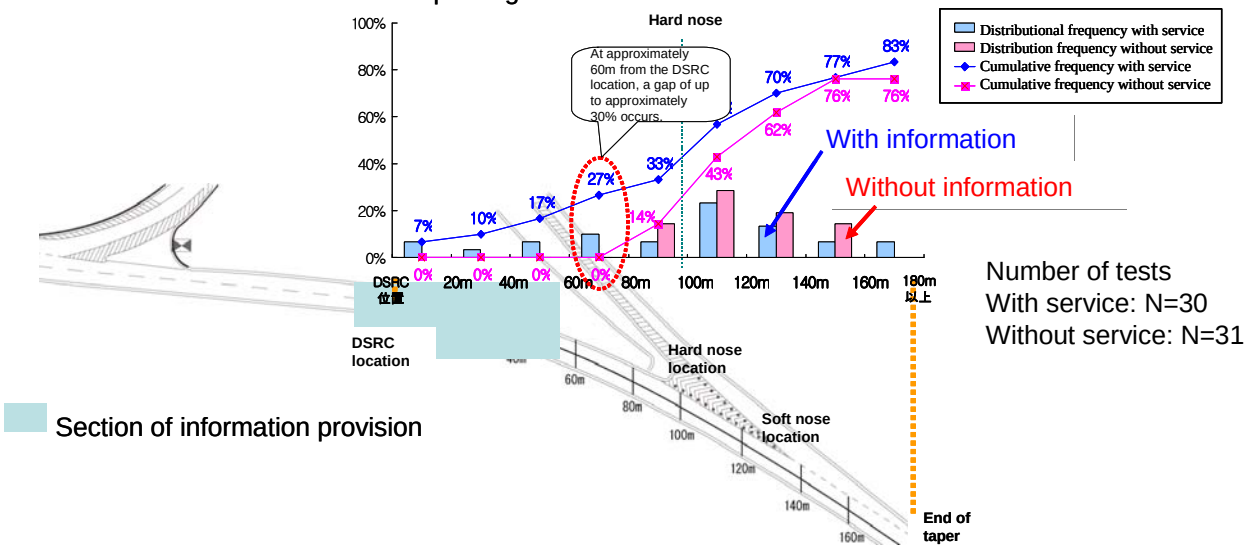

Figure 11. Distribution of positions where the test drivers prepare for deceleration at Tanimachi Junction

4.3 Support for prevention of overshooting on curve

Support for prevention of overshooting on curve is a service which alerts each vehicle entering a curve at high speed according to the speed of each one. And it can also provide information according to circumstances: by lowering the speed threshold for issuing warnings on wet condition by monitoring the state of the road surface with sensors.

A field operational test on Hanshin Expressway, Route No. 14 Matsubara Line, Miyake Curve (inbound), measured vehicle speed by obtaining ID in the measurement section using the ETC-ID as described above. Figure 12 presents an outline of the Preventing Danger Entering Curves system on the Miyake Curve.

Here, the results of the tests on the Miyake Curve using the ETC-ID method are introduced. Table 3 shows the DSRC roadside unit pass-through time and average speed at the approach to the curve by service. It confirmed that vehicles entering at high speed reduced their speed at the curve entrance to a lower speed with the service than without the service.

Figure 13 shows the results of the questionnaire survey. About 80% of survey subjects using navigation linked service, and 60% of survey subjects using speech type gave answers indicating deceleration action—“I felt I should watch out”, “I felt I should slow down”, and “I was a little startled but I felt I should watch out”—confirming that providing the information made the test subjects more conscious of safety.

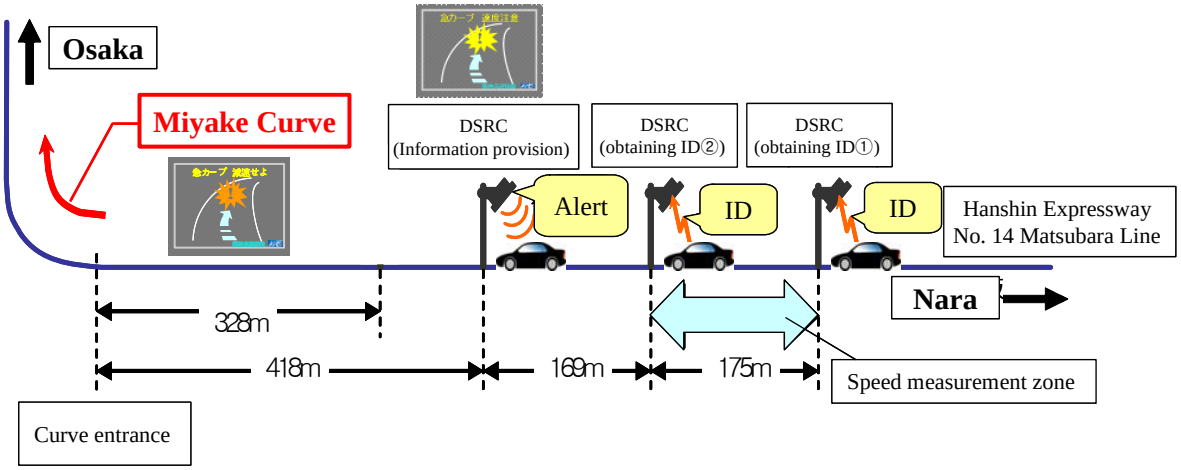

Figure 12. Image of Support for prevention of overshooting on curve at the Miyake Curve

Table 3. Pass-through Speed and Average Speed at Curve approach by Service

Service		Speed During DSRC RSU Pass-through Km/h	Curve Approach Speed Km/h
Navigation-linked OBU	Overall N=30	92.82	74.43
	High speed vehicle N=8	**104.36**	**84.06**
Speech type OBU	Overall N=16	87.42	77.20
	High speed vehicle N=4	**103.77**	**78.57**
without Service	Overall N=41	92.38	77.09
	High speed vehicle N=7	**104.91**	**84.81**

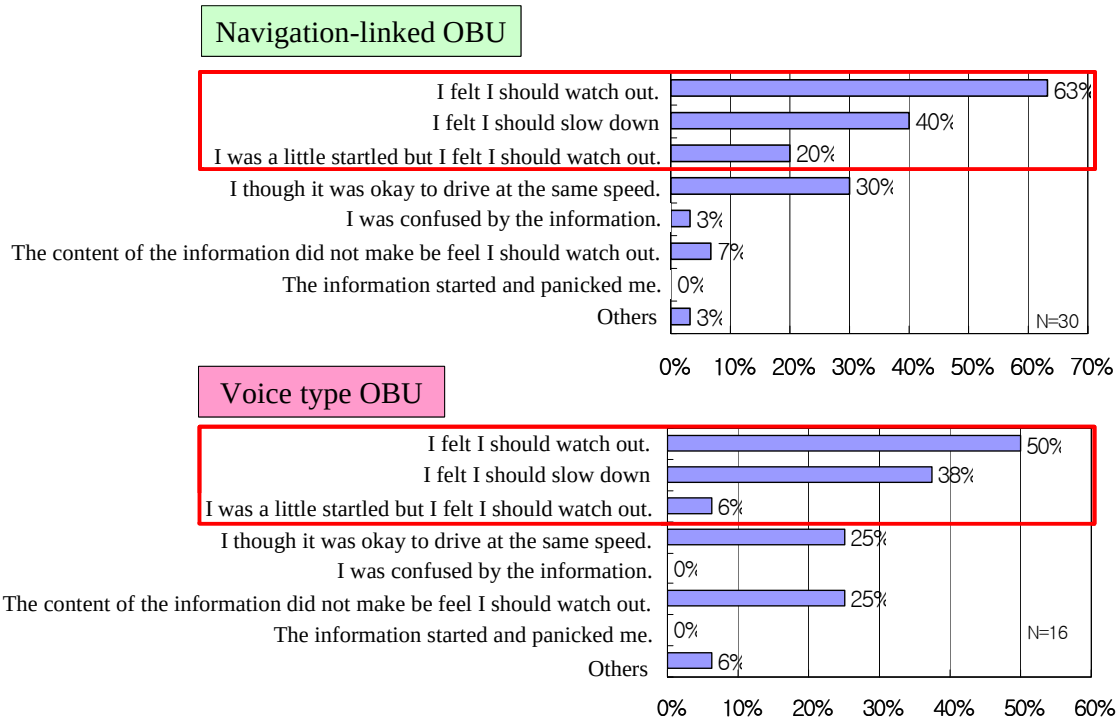

Figure 13. Results of Questionnaire Survey Concerning Assistance Preventing Danger Entering Curves at the Miyake Curve

5. Summary

The MLIT conducting field operational tests in FY2007 and in FY2008, and Smartway Demo 2007, confirmed the effectiveness of information provision and also confirmed that providing information does not cause negative reactions such as sudden deceleration or abrupt steering. In the future, services will be tested in combination to obtain further knowledge to promote Smartway with the aim of introducing it as a fully operational system.

References

1 Hideto Hatakenaka, Koichi Sakai et al, "Proving Tests of the Forward Obstacles Information Provision Service Using the ETC-ID System" 15th World Congress on ITS, Nov. 2008

2 Hideyuki Kanoshima, Takao Aya et al, "Development and Verification of Effectiveness of an AHS Safe Merging Support Service" 15th World Congress on ITS, Nov. 2008

3 Satoshi Fujimoto, Koichi Sakai et al, "Toward Realization of Smartway in Japan" 15th World Congress on ITS, Nov. 2008